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Forecasting completion of the pre-engineering curriculum at the University of Omaha

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NOTE TO USERS

FORECASTING COMPLETION OF THE PRE-ENGINEERING CURRICULUM AT THE UNIVERSITY OF OMAHA

by

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I. INTRODUCTION

The will to survive is a fundamental motivating force which preserves the human race. In a culture as advanced as ours, mere maintenance of life has become, with limitations, a relatively minor problem. However, survival in a chosen field of endeavor presents perplexities which have not been reduced but rather increased by scientific progress. The psychological implications involved in determining factors related to success are numerous. Particularly with respect to an academic curriculum offering preparation for a degree in engineering it is necessary to evaluate accurately the factors necessary for success.

An area of specialization in which survival in particularly difficult is the curriculum designed for engineering. If the need for adequately-trained engineers is to be satisfied, continued effort must be exerted to guide students who possess the aptitudes and interests essential to success in engineering into a college curriculum offering preparation for that profession. Especially in the past decade has this responsibility of guidance been increasingly undertaken by specialists in counseling and psychometric measurement. Institutions of higher learning, with few

exceptions, have established counseling and testing services for the guidance of students.

The present investigation is concerned with the determination of factors related to student achievement, aptitude and interest which may be utilized for predicting survival in the pre-engineering curriculum at the University of Omaha. Success in a pre-engineering curriculum does not, presumably, insure the student ultimate success in obtaining a degree from a four- or five-year curriculum in a college of engineering. However, the analysis and meaningful interpretation of the results of psychometric measures by the counselor may contribute to the reduction of the attrition of students endeavoring to complete a curriculum leading to an engineering degree. The University of Omaha has in operation a counseling and testing program. Much of the information for the present investigation was obtained therefrom. An effort has been made to provide in subsequent chapters a practical tool whereby the counselor might predict the probability of survival of a student in pre-engineering.

II. THE UNIVERSITY OF OMAHA[1]

The University of Omaha was incorporated as a co-educational non-sectarian college in 1908. In 1928, the legislature of Nebraska authorized cities of the metropolitan class to establish and maintain municipal universities. On May 6, 1930, the citizens of Omaha voted to establish the Municipal University of Omaha. In January, 1931, the first University Board of Regents selected by the Omaha Board of Education assumed control over the old University of Omaha. In 1937-1938 a new university building was constructed in a new location on a fifty-one acre site. This structure was financed by accrued building funds and a grant from the Public Works Administration. Several temporary structures were erected to accommodate the increased enrollment following World War II. In 1949, $750,000 was spent for a field house and playing fields to provide indoor and outdoor facilities in all sports.

Since its establishment as a municipal institution, the University of Omaha, like other colleges and universities, has revised its various curricula and improved its laboratory and library facilities in an attempt to meet the

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[1] University of Omaha, Bulletin of the University of Omaha, Vol. 16, No. 1. Omaha, Nebraska. February, 1951.

changing needs in education. The present administrative organization is headed by President P. M. Bail, formerly at Butler University as Dean of the College of Education and Director of the University College. The University of Omaha is accredited by the North Central Association of Colleges and Secondary Schools.

The curricula at the University of Omaha have been designed to provide a liberal education through a study of the humanities, the social sciences, and the natural sciences. The program for the first two years is designed to furnish a general education as a preparation for specialization. Two-year pre-professional training in law and medicine is available as well as two-year programs in accounting, engineering, home economics, journalism, marketing, and secretarial training. Successful completion of the lower division establishes eligibility for the title of Associate. The last two years of study at the university provide an opportunity for the student to develop special interests. The major fields of study are business administration, economics, education, English, music, art, foreign languages and literature, history and government, speech, mathematics, psychology, science, sociology, business and engineering administration, home economics, journalism, medical technology, military science, nursing, and retailing. Upon successful completion of a four-year program a bachelor's

degree is obtainable. The University of Omaha also provides training for a professional career in teaching. Areas of specialization are kindergarten-primary education, elementary education, secondary education, physical education, special education, and health education. The degree of Bachelor of Science in Education is conferred upon successful completion of the four-year program, and through proper selection of courses eligibility for a Nebraska Teaching Certificate is established. In addition the University of Omaha offers graduate training in a limited number of fields. A Master of Arts degree may be obtained through graduate study in psychology, education, sociology, and English, with minor studies in mathematics and science. A Master of Science in Education degree is available to individuals interested in a career as a teacher, a supervisor, or an administrator.

The average yearly enrollment of the University of Omaha during the four years immediately following World War II was approximately 3800 students of which one-half were in the adult education program. The two major divisions of the adult education program are the division of general education and the division of technical institutes. The division of general education is divided into three sections. The extension section offers a selection of general and professional courses in the liberal and applied arts and sciences for adults and part-time students who wish to obtain an academic degree or professional certificate. A second

section, the general section, offers courses of a general, cultural, and vocational nature to meet the needs of adults who seek to keep their education up-to-date. Finally, the division of general education includes the community service section. This section offers lectures, forums, clubs, institutes and similar services which may be arranged to meet the needs of special groups. In connection with the division of general education a daily classroom television program is offered for credit. In the division of technical institutes, training is provided for adults who have no particular desire to complete a formal college education. Course offerings provide opportunities to gain an education in technical and mechanical fields, such as radio, tool and die engineering, machine shop, stationary engineering, plastic novelties, building contract estimating, quality control, small business management, and insurance. Programs of study in the various vocational areas are outlined through the combined effort of local business and industrial executives and the university officials. Many of the men on the teaching staff of the various institutes are prominent in the city's manufacturing and industrial firms.

The University of Omaha provides its students with a tutoring service, a supervised study center, and a placement service. Over 50 annual scholarships and tuition grants are available to students. The university library has a general

book collection of over 85,000 volumes with an additional 15,000 government documents and 400 current periodicals. The Bureau of Adult Testing, Guidance, and Personnel Services is responsible for all testing of entering students. Psychological, psychometric, and counselling services are available to students of the university. Such services are also available to business and industrial organizations on a fee basis.

The University of Omaha as here outlined would seem to be typical of municipally owned universities with respect to education of students and services offered to the community.

III. REVIEW OF LITERATURE

Numerous investigations have been made to predict academic achievement on the basis of objective measures of aptitude, previous achievement, interest, personality, and other psychological measuring techniques. However, studies dealing with prediction of attrition-survival tendency at various stages of an academic curriculum are not nearly so abundant. The review of literature has been limited to those studies which are especially pertinent to the present investigation.

Higgins[2] investigated the records of 153 graduates of the School of Engineering at Cornell University. He was concerned with the relationship between mathematical achievement and academic success in the engineering curriculum. Success in engineering was measured by the four-year grade point average of the student. Mathematics ability was measured by the average grade obtained in analytic geometry and calculus. When the students were grouped according to mathematical achievement and the groups were compared with respect to four-year grade point average, it was found that

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[2] Higgins, T. J., Study of Mathematical Ability in Relation to Success in Engineering Studies. Journal of Engineering Education. 23:743-746. June, 1933.

engineering success decreased with a decrease in mathematics average. The correlation between engineering success and mathematics average was 0.84. Higgins concluded that if a definite positive relationship could be established between achievement in secondary school mathematics and academic success in engineering school, a useful way of choosing those applicants who will be successful in engineering schools will be realized.

Minor[3] investigated the effectiveness of the nine interest scores of the Kuder Preference Record when used in combination with other variables for the purpose of predicting first quarter grade point average of freshman engineering students. Other prediction variables were the Owens-Bennett Test of Mechanical Comprehension score, high school grade point average, and American Council on Education Psychological Examination score. A combination of all twelve variables yielded a multiple correlation of 0.63. When the nine interest scores were eliminated from the prediction equation, the multiple correlation decreased only to 0.61. The loss was not significant.

McRae[4] investigated the usefulness of the five subscores

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[3] Minor, W. T., Usefulness of the Kuder Preference Record for Predicting Academic Success of Iowa State College Engineering Freshmen. Unpublished M. S. Thesis. Ames, Iowa, Iowa State College Library. 1947.

[4] McRae, J. M., Usefulness of the Minnesota Personality Scale for Predicting Achievement of Freshman Engineering Students. Unpublished M. S. Thesis. Ames, Iowa, Iowa State College Library. 1949.

of the Minnesota Personality Scale when used in combination with other variables in predicting first-quarter grade point average of freshman engineering students. The other prediction variables were the American Council on Education Psychological Examination score, high school grade point average, and the Owens-Bennett Test of Mechanical Comprehension score. Combining each of the five subscores of the Minnesota Personality Scale with the other three variables, multiple regression equations and discriminant functions were developed. No significant losses occurred when any of the five Minnesota Personality Scale subscores were eliminated from the prediction battery.

The relationship of five aptitude variables to achievement in basic engineering courses included in the first-year curriculum at Iowa State College was investigated by Schmitz.[5] The five aptitude variables selected were high school grade point average, score on the American Council on Education Psychological Examination, score on the English Placement Test for Iowa Universities and Colleges, score on the Owens-Bennett Mechanical Comprehension Test, and the score on the Iowa State College Mathematics Placement Test.

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[5] Schmitz, Roy M., Relationship of Certain Measured Abilities to Freshman Engineering Achievement. Unpublished M. S. Thesis, Ames, Iowa, Iowa State College Library. 1952.

Correlations were computed between the five aptitude variables and first-year engineering grade point average for two levels of achievement, 2.00 or above (4 point scale) and the upper ten per cent scholastically. At the 2.00 position biserial coefficients of correlation ranged from 0.35 for the Mechanical Comprehension test to 0.61 for the high school average. At the ten per cent position the biserial coefficients of correlation indicated a low of 0.34 for the Mechanical Comprehension test and a high of 0.65 for the English Placement test. Multiple biserial coefficients of correlation at the two achievement levels were 0.72 and 0.77 respectively. Discriminant functions and abbreviated tables for prediction were developed for each of the two criteria.

Betts[6] reported a study concerning 287 male freshmen at the Iowa State College. The purpose of the study was to predict the probability of survival in the first course in chemistry for students enrolled in the Division of Agriculture. The students were divided into eight groups as follows:

(1) Students entering college with credit in high school chemistry;

(2) Students entering college without credit in high school chemistry;

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[6] Betts, M. E., Probability of Mortality in First-Quarter Chemistry for Students of Agriculture at Iowa State College. Unpublished M. S. Thesis. Ames, Iowa, Iowa State College Library. 1952.

(3) Students entering college with credit in vocational agriculture;

(4) Students entering college without credit in vocational agriculture;

(5) Students enrolling in the first course in chemistry with credit in high school chemistry;

(6) Students enrolling in the first course in chemistry without credit in high school chemistry;

(7) Students enrolling in the first course in chemistry with credit in vocational agriculture;

(8) Students enrolling in the first course in chemistry without credit in vocational agriculture.

Discriminant functions with high school average and American Council on Education Psychological Examination score as prediction variables were found for each of the eight foregoing groups. Discriminant functions corresponding to the first four groups were developed to predict attrition-survival tendency in the first course in college at the time the student entered college. Discriminant functions corresponding to the last four groups were for the purpose of prediction of attrition-survival tendency in the first course in chemistry at the time the student enrolled in chemistry.

Betts resolved the tendency to survive the first course in chemistry into a trichotomy composed of (1) students who received a passing mark in the course, (2) students who received a failing mark in the course or transferred to a decelerated course at midterm, and (3) students who dropped out of college before enrolling in the first course in

chemistry. Significant triserial correlations between the tendency to survive the first course in chemistry and the two prediction variables ranged from 0.235 to 0.666 for the eight groups into which the students were divided.

At the University of California Siemens[7] developed a prediction equation for predicting achievement of upper division engineering students. A multiple regression equation was derived from the records of 1400 students in four engineering curricula. The criterion of academic success in engineering was grade point average in all upper division engineering courses. Five prediction variables were employed. They were: (1) grade point average of the first semester of upper division engineering, (2) grade point average of all lower division courses, (3) grade point average of college mathematics, (4) grade point average of college physics, and (5) grade point average of college chemistry. Correlation coefficients between the criterion and each of the prediction variables were 0.87, 0.70, 0.69, 0.69 and 0.61, respectively.

A multiple regression equation for predicting upper division engineering grade point average from the five prediction variables was tested on 200 cases. A correlation

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[7] Siemens, C. H., Forecasting the Academic Achievement of Engineering Students. Journal of Engineering Education. 32:617-621. April, 1942.

of 0.89 was obtained between actual and predicted values.

A variation of discriminant analysis was employed by Sprain[8] at Iowa State College. The discriminant function was used to predict three categories of achievement in chemistry. The study was limited to 800 students of the Engineering and Science Divisions who registered for the first course in chemistry in the fall of the years 1947 through 1950. These students were divided into attrition, average, and top groups according to whether they dropped or failed, received a mark of C or D, or received a mark of A or B, respectively, in the first course in chemistry. The attrition-average-top chemistry trichotomy was considered the criterion of achievement. Prediction variables were American Council of Education Psychological Examination score, high school grade point average, and Carnegie units of high school mathematics. Triserial correlations between the chemistry trichotomy and each of the three prediction variables in the order given in the preceding statement were 0.4947, 0.5643, and 0.3395, respectively. The multiple triserial correlation between the three prediction variables and the chemistry trichotomy was 0.6673. One discriminant function was obtained using American Council of Education

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[8] Sprain, Wilbur, Extension of the Discriminant Function for Evaluating High School Chemistry as a Prerequisite for College Chemistry. Unpublished Ph. D. Thesis. Ames, Iowa, Iowa State College Library. 1952.

Psychological Examination scores as prediction variables. Another discriminant function was obtained using high school grade point average and Carnegie units of high school mathematics as prediction variables. The two discriminant functions were expressed so as to produce sigma scores of attrition-average-top tendency which could be interpreted as probabilities. Finally, probability tables showing chances in 100 of being in the three groups of the chemistry trichotomy were prepared.

Stuit[9] has summarized the results of numerous investigations which have correlated success in the engineering curriculum with various prognostic factors pertaining to student achievement, aptitude, and interest. The report included investigations performed as early as 1927 and as recently as 1944. Grade point average was the criterion of success in the engineering curriculum in all of the investigations mentioned. The stages of collegiate progress for which grade point averages were computed varied from study to study but were limited to the four following: the end of the first semester, the end of the first year, the end of the second year, at the time of graduation.

It is not the function of the present investigation to

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[9] Stuit, Dewey B., and others, Predicting Success in Professional Schools. American Council on Education Studies, Series 6, Personnel Work in Colleges and Universities. 1949.

report the multitudinous correlations between engineering success and single factors and batteries of factors related to student achievement, aptitude, and interest which were included in the Stuit compilation of research studies. However, the conclusions drawn by Stuit as a result of his research are useful in the counseling of prospective engineering students. First, high school or college grade point averages furnish one of the most reliable estimates of academic success in a collegiate engineering course. Second, tests of general scholastic aptitude provide reliable sources of information concerning a student's potentialities for success in an engineering curriculum. Third, proficiency in mathematics, whether represented by achievement test scores or grades in high school and college mathematics, constitute a valuable source of predictive data. Fourth, competence in the sciences, particularly physics, is important to satisfactory achievement in the engineering curriculum but is not as essential as mathematical proficiency. Fifth, a well developed vocabulary and command of English grammar are necessary for reading technical literature and in writing descriptive reports. English usage ability correlated significantly with achievement in engineering school. Sixth, ability or aptitude or vizualization of spatial relationships and the understanding of basic mechanical principles are significantly correlated

with engineering achievement while manipulative skill or dexterity is not. Seventh, interest inventory scores show little correlation with scholarship in engineering. However, interest test scores may be valuable in revealing latent interest in areas associated with engineering success. Eighth, and last, in no instance was any psychological measure investigated so closely related to achievement in engineering that it alone could be relied upon as a prediction of individual success. However, the use of all the measures of achievement, aptitude, and interest combined with other information concerning the student should improve the accuracy of the prediction of his chances of success in a college engineering curriculum.

Kandel[10] in 1940 reviewed two decades of attempts to determine factors of greatest prognostic value for success in a collegiate engineering curriculum. His conclusions agreed in general with those of Stuit. Kandel, too, stressed the importance of past achievement in mathematics as a predictor of future success in an engineering curriculum. He also pointed out the need for further research to determine the factors most valuable for predicting survival in engineering colleges.

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[10] Kandel, I. L., Professional Aptitude Tests in Medicine, Law, and Engineering. Teachers College, Columbia University. New York. 1940.

Freund[11] reported an investigation of attrition students at the University of Detroit. A questionnaire was sent to 986 former students of the college of engineering who failed to graduate. Approximately a 25 per cent return was received on the 840 deliverable questionnaires. The purpose of the survey was to determine whether the student gained anything from his attempts to learn the subject matter of the engineering curriculum.

Several conclusions were drawn from the information available from the returned questionnaires. It was found that a considerable percentage of non-graduating former students derived benefits from completing a portion of the engineering curriculum, both in their employments and in their humanistic-social development. The benefits were apparently sufficient to justify the time, effort, and funds which the students expended for their schooling. Another observation was that the engineering faculty might well be in error in advising withdrawing students to avoid jobs in engineering and industry. A third conclusion was that it might be well to reconstruct curricula so that the student could complete an integrated system of courses at the close of each successive year. A final observation was that

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[11] Freund, C. J., Is Less Than Graduation Worthwhile? Report of the Engineering College Administrative Council presented before the Society for Engineering Education at Michigan State College. 1951. (Mimeographed.)

traditions, policies, attitudes, and procedures might be revised so that no reflection shall be cast upon the student who is unable to graduate for one reason or another.

In connection with the last two of the foregoing conclusions it was pointed out that some universities grant certificates to students who leave before graduating. A statement from the 1930 Report of Investigation of Engineering Education was mentioned and stated in effect that it might be proper to issue associate Certificates in Engineering at the completion of the first two years' work.

Flesher[12] was interested in determining whether or not the Cooperative General Mathematics Test and the Cooperative English Test had any predictive value beyond that offered by the Ohio State University Psychological Examination. The criterion of engineering achievement used was first semester college point hour average. Prediction variables were: age at entrance to university, percentile rank on the Ohio State University Psychological Examination, score on the Cooperative General Mathematics Test, score on the Cooperative English Test, and number of units of high school mathematics. Flesher found that age, units of high school mathematics, and score on the Cooperative English Test could be

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[12] Flesher, Marie A., Prediction of Freshman Achievement in the College of Engineering, Ohio State University. Unpublished M. S. Thesis. Columbus, Ohio, Ohio State University Library. 1935.

eliminated without significant loss in predictive efficiency. She concluded that the score on the Cooperative General Mathematics Test was the best single variable for prediction.

Bailey[13] used the discriminant function to forecast the probability of graduation of freshmen entering the College of Engineering at the University of New Mexico. The prediction variables used were: units of high school mathematics, first semester college grade point average, and the quantitative and linguistic scores of the American Council on Education Psychological Examination. A multiple biserial correlation of 0.56 was found between the attrition-survival dichotomy and a combination of all of the prediction variables. Chances in 100 of graduating ranged from 14 in 100 to 64 in 100 on the basis of the four variable discriminant functions. When all variables except first semester grade point average were dropped, no significant loss in the efficiency of prediction occurred.

Ahmann[14] employed the discriminant function technique to predict the probability of graduation in engineering at

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[13] Bailey, A. P., Forecasting Graduation Probabilities for Engineering Students at the University of New Mexico. Unpublished M. S. Thesis. Ames, Iowa, Iowa State College Library. 1950.

[14] Ahmann, J. S., Prediction of Achievement of Iowa State College Engineering Students Having Transferred from Other Institutions. Unpublished Ph. D. Thesis. Ames, Iowa, Iowa State College Library. 1951.

Iowa State College for transfer students from other colleges and from junior colleges. The two most efficient prediction equations found were: a two variable equation, based on the quantitative score on the American Council on Education Psychological Examination and high school grade average; and a single variable equation based on first quarter college grade point average at Iowa State College. The subjects of Ahmann's study were stratified according to veteran status and according to whether they had attended a junior college or another college before coming to Iowa State College. Using these four classifications, four groups were distinguishable among the transfers to Iowa State College:

(1) Veterans who had attended a junior college,

(2) Non-veterans who had attended a junior college,

(3) Veterans who had attended another college,

(4) Non-veterans who had attended another college.

For purposes of summarization, students were categorized as superior, average, and inferior according to their performance with respect to the prediction variables used in the discriminant function.

When students were grouped according to performance on the quantitative score of the American Council on Education Psychological Examination and high school grade average, probabilities of survival were:

	(1)	(2)	(3)	(4)
Superior	50	35	63	40
Average	31	18	43	23
Inferior	13	06	12	08

When students were classified according to first quarter grade point average at Iowa State College, probabilities of survival were:

	(1)	(2)	(3)	(4)
Superior	66	58	75	62
Average	32	25	42	28
Inferior	11	07	16	09

A study closely related to the present investigation was carried out by Dean.[15] Of the group of students who entered the engineering curricula at Iowa State College in the fall quarter of 1950, 60 per cent survived to the fourth quarter, 30 per cent graduated, and 15 per cent graduated in the upper half of the class. For each of the three foregoing categories, Dean developed probability tables to predict chances in 100 of survival in engineering by means of the discriminant function. The prematriculation information used as prediction variables was the quantitative and

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[15] Dean, T. C., Prediction of Achievement of Native Students in Engineering at Iowa State College. Unpublished Ph. D. Thesis. Ames, Iowa, Iowa State College Library. 1951.

linguistic scores from the American Council on Education Psychological Examination, the speed and comprehension scores from the Iowa State College Silent Reading Test, the score on the United States Armed Forces Institute Test on Correctness and Effectiveness of Expression, the score on the college level English Placement Test, the score on Iowa State College Mathematics Placement Test, and high school grade point average. Prediction variables from first year college engineering were: grade point average at the end of the first quarter, first quarter achievement in all sequence courses required of freshman engineering students, and achievement in freshman engineering courses through the first year. Probabilities of surviving to the fourth quarter, of graduating, and of graduating in the upper one-half of the class are reported in the three following paragraphs respectively.

From the quantitative score on the American Council on Education Psychological Examination and high school grade point average combined, a probability table indicated a range of from 30 chances in 100 to 82 chances in 100. Prediction of fourth-quarter attrition-survival tendency was obtained by using first-quarter college grade point average with no significant loss in prediction efficiency incurred in dropping the two prematriculation variables.

From the same combination, the Quantitative score on the American Council on Education Psychological Examination

and high school grade point average, probability of graduation in engineering was predicted. Here, probabilities of survival ranged from 9 chances in 100 to 57 chances in 100. Again the two prematriculation variables were dropped without significant loss and a better prediction scheme obtained by using first-quarter college grade point average. However, average achievement in the chemistry and mathematics courses of first-year engineering proved to be superior in prediction variables without significant loss due to the two prematriculation variables and first-quarter college grade point average. The probabilities of graduation based on first-year chemistry and mathematics ranged from 20 in 100 to 82 in 100.

Finally, three prediction schemes were derived for tendency to graduate in the upper half of the graduating class in engineering. The first scheme, based on the Quantitative and Linguistic scores of the American Council on Education Psychological Examination, yielded probabilities ranging from 3 in 100 to 35 in 100. A second scheme, based on first quarter college grade point average alone, gave probabilities of from 6 in 100 to 30 in 100. And the third scheme based on first-year mathematics and chemistry achievement indicated chances of from 6 in 100 to 62 in 100 for graduating in the upper half of the graduating class.

Prediction of achievement by means of multiple regression based on various numerically expressed psychological

measures is undoubtedly of value to the counselor in advancing suggestions concerning the probability of success in any particular area of study. However, a more readily-understood tool for predicting the attrition-survival tendency of a student in a given curriculum is the probability table. By use of this device the counselor can state on the basis of the various prediction variables the probability of successful completion of a given curriculum by a particular student. If the prediction variables are closely related to the attrition-survival tendency, the probabilities of survival derived are much more meaningful than a mere statement of the percentage of attrition for a particular group over a specified time interval.

IV. METHOD OF PROCEDURE

The purpose of the present investigation was to forecast the attrition-survival tendency of a student entering the pre-engineering curriculum at the University of Omaha. Probabilities of survival were developed for three stages of educational progress: (1) upon graduation from high school, (2) upon administration of the University of Omaha entrance examinations, and (3) upon completion of first semester college mathematics.

The time interval covered by the study extended from September, 1946, through September, 1949. During this interval 403 students who were graduates of Omaha, Nebraska, and Council Bluffs, Iowa, public high schools entered the pre-engineering curriculum at the University of Omaha. Graduates of public high schools other than those in Omaha and Council Bluffs were excluded to eliminate any bias due to size and geographical location of high school. Such a delimitation seemed feasible in that the great majority of the students entering the University of Omaha were graduates of Omaha and Council Bluffs high schools. A second delimitation required that a student must have taken one unit of high school mathematics to be included in the investigation. The latter restriction and the fact that data with respect

to one or more of the eighteen variables to be considered for subsequent predictions of survival were unobtainable for some students reduced the total number of cases to 375.

The pre-engineering curriculum at the University of Omaha is a two-year course. For purposes of selecting those students who successfully completed the pre-engineering curriculum, a passing mark in second semester calculus was chosen as the criterion of survival. Similarly, those students who did not receive a passing mark in second semester calculus were considered in the attrition group. These definitions placed 86 students in the survival group and the remaining 289 in the attrition group. Although several criteria of survival were considered, the one chosen seemed most suitable for several reasons. One possibility was to place in the survival group only those students who had applied for admission to a four-year college of engineering. However, the records at the University of Omaha furnished no evidence as to whether such students actually attended the college where they had applied for admission. Another possibility was to place only those students who later actually received a bachelor's degree in engineering in the survival category. However, the task of gathering such information presented a seemingly insurmountable obstacle. Successful completion of second semester calculus as a criterion of survival seemed justified in that it is the last course in

the sequence of mathematics courses required of a student enrolled in the pre-engineering curriculum at the University of Omaha. The fact that several of the investigations reported in the review of literature concerning academic success in engineering emphasize the importance of successful achievement in mathematics seemed to justify the use of the chosen criterion.

A brief account of the subsequent academic progress of the survival group will help to characterize those students. Fourteen of them received a Bachelor of Science degree from the University of Omaha. Thirty-seven of them sent transcripts of credits to Iowa State College and nineteen of these are known to have entered Iowa State College to study engineering. Sixteen of the survival group sent transcripts of credits to the University of Nebraska and eight of this group are known to have entered the engineering curriculum at that university. Twenty-five of the students in the survival group received the Associate Title Certificate upon completion of the two-year engineering course at the University of Omaha.

A student who was classified in the attrition group was not necessarily a failure. The definition of attrition postulated in the present investigation necessarily included in the attrition category students who transferred, prior to the completion of the pre-engineering curriculum, to a four-year engineering program at another institution

and students who transferred to a curriculum other than pre-engineering at the University of Omaha before the end of the sophomore year. Some of these students successfully completed a four-year college program.

From the records at the University of Omaha 18 factors were available which were conceivably of prognostic value in determining the success of a student entering the pre-engineering curriculum. These variables and the stages of educational progress with which they were associated for purposes of prediction are given below.

At the time the student graduated from high school, the factors used to predict survival were:

(1) number of Carnegie units of high school mathematics, and

(2) mean high school mathematics mark.

The fifteen factors chosen for predicting survival from test results of the University of Omaha entrance examinations were:

(1) age upon entrance to the University;

(2) Ohio State University Psychological Examination raw score, hereinafter called the O.C.A. score;

(3) the Cooperative English test--total raw score, hereinafter called the English test score;

(4) Minnesota Reading Test--speed raw score, hereinafter called the reading speed score;

(5) Minnesota Reading Test--comprehension raw score, hereinafter called the reading comprehension score;

(6) the Wrenn Study Habits Inventory score, hereinafter called the study habits score;

and the following raw scores from the Kuder Preference Record:

(7) scientific interest,

(8) mechanical interest,

(9) computational interest,

(10) persuasive interest,

(11) social service interest,

(12) literary interest,

(13) musical interest,

(14) artistic interest, and

(15) clerical interest.

The third prediction of survival was based on only one variable. That variable was a student's mark in the first semester of mathematics at the University of Omaha.

In order to facilitate computation, code values were assigned to three of the foregoing variables. High school and college mathematics marks A, B, C, D, and F were assigned the values 4, 3, 2, 1, and 0, respectively. College mathematics marks of Withheld, Drop, and Condition were included in the F category. Ages 16 through 28 were assigned values 0 through 13, respectively.

A preliminary analysis of the eighteen prediction variables served a dual purpose. It revealed the more obvious

relationships between the prediction variables and the attrition-survival tendency, and it provided a method of selecting the variables most closely associated with attrition-survival tendency at each of the three stages of educational progress chosen for prediction. The first step in the preliminary analysis consisted of finding the differences in means of the attrition and survival groups with respect to the prediction variables and of computing standard deviations of the variables for the total sample. The second step consisted of computing biserial correlations between each of the eighteen prediction variables and the tendency to survive. The biserial correlations were then tested for significance. The variables which yielded a highly significant correlation with survival tendency were used to predict survival in the pre-engineering curriculum.

The first prediction of survival was made at the time of high school graduation since it was based solely upon high school mathematics experience. Two discriminant equations were developed using the high school mathematics variables. However, discriminant equations as such do not furnish the counselor a ready instrument for guidance. Therefore, two probability tables were constructed from the two discriminant equations. Such tables indicated a student's chances in 100 of successfully completing the pre-engineering curriculum on the basis of high school mathematics experience.

It should be noted that the discriminant equation which is used here is a departure from the type of discriminant analysis indicated by Fisher.[16] The members of the dichotomy which he defined were assumed to be drawn from two separate normally distributed populations. The attrition-survival characteristic described in the present investigation is assumed to be drawn from a single normally distributed population.

A second prediction of survival was made from test scores obtained from University entrance examination. Variables not significant in predicting survival at this stage of educational progress were eliminated. Again two prediction equations and the corresponding probability tables were developed. Thus, a student's probability of successfully completing the pre-engineering curriculum could be forecast upon completion of University entrance examinations.

Finally, a prediction equation based upon first semester college mathematics mark was obtained. The corresponding probability table yielded chances in 100 of completing pre-engineering at the University of Omaha after completion of first semester college mathematics.

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[16] Fisher, R. A., The Use of Multiple Measurements in Taxonomic Problems. Annals of Eugenics. 7:179-188. 1936.

V. SINGLE VARIABLE RELATIONSHIPS TO ATTRITION-SURVIVAL TENDENCY

The first step in the preliminary analysis provided information essential to subsequent discriminant analysis and provided an overview of the relative importance of the prediction variables in forecasting attrition-survival tendency. This preliminary computation consisted of determining differences between the means of the attrition and survival groups with respect to the eighteen prediction variables and of determining standard deviations of the variables for the total number of cases. The results of the computations classified as to stage of educational progress are shown in Table 1.

With respect to the prediction variables used at the time of high school graduation it is seen that the mean high school mathematics mark of the survival group is on the average 0.7 of a grade point higher than that of the attrition group, and it is evident that the survival group had on the average approximately 0.6 of a school year more high school mathematics than did the attrition group. The actual values of the mean high school mathematics mark for the attrition and survival groups were 2.37 and 3.05 respectively. The mathematics achievement of the attrition group

Table 1.

Differences in Means of the Attrition and Survival Groups and Standard Deviations for Total Number of Cases with Respect to the Prediction Variables

Stage of educational progress	Prediction variable	Differences in means	Standard deviations for total number of cases
High school graduation	Mean high school mathematics mark	0.68	0.83
	Units of high school mathematics	0.58	1.10
College entrance	O.C.A.	16.22	24.51
	English entrance test	27.54	45.10
	Reading speed	1.72	4.73
	Reading comprehension	7.11	12.84
	Study habits	17.61	48.17
	Age	-0.16	2.19
	Kuder Preference Record		
	Mechanical interest	-1.72	14.96
	Computational interest	1.93	9.89
	Scientific interest	5.80	14.34
	Persuasive interest	-3.04	15.21
	Artistic interest	-3.24	13.27
	Literary interest	2.20	13.37
	Musical interest	-1.02	9.06
	Social service interest	0.40	15.04
	Clerical interest	-2.87	11.55
First semester college	First semester college mathematics mark	1.20	1.20

was approximately one-third of a grade-point above an average of 2.00, while the mathematics achievement of the survival group was one whole grade-point above average. Actual values of the means for number of units of high school mathematics for the attrition and survival groups were 2.59 and 3.17 respectively. Thus, the attrition group had had approximately two and one-half years of high school mathematics, while the survival group had had slightly more than three years of high school mathematics.

All test scores chosen for prediction of survival at the time of college entrance were raw scores. Therefore, a comparison of size of two differences in means corresponding to two particular prediction variables is meaningless. For example, the fact that the difference in means of the attrition and survival groups is given by the same numerical value for the O.C.A. score and for study habits test score does not indicate that those two variables are equally important in predicting attrition-survival tendency. In fact, O.C.A. scores will be shown to be much more useful for the prediction of survival than study habits scores. Inspection of the broad fluctuation of standard deviation values will also eliminate errors in interpretation of differences in means. For example, it is obvious from Table 1 that the variability of study habits test score is twice as great as the variability of O.C.A. score. Therefore, a

comparison of the value for differences in means only with respect to the two variables defies interpretation.

Meaningful interpretations are, however, possible with respect to the variables used to predict survival at the time the student matriculated. These interpretations concern differences in performance of the attrition and survival groups with respect to each of the college entrance examination test scores. From Table 1 it is seen that the survival group scored approximately sixteen raw score points higher on the average on the O.C.A. than did the attrition group. With respect to the scores on the Kuder Preference Record it is seen that the survival group scored approximately six points higher on the average on scientific interest than did the attrition group; whereas negative differences in means indicated that the attrition group scored approximately three points higher on the average on persuasive interest, artistic interest, and clerical interest than did the survival group. Two variables which proved useful in subsequent predictions of survival were O.C.A. score and scientific interest score. Actual values of the mean O.C.A. score for the attrition and survival groups were 67.60 and 83.82 respectively. The raw score corresponding to the fiftieth percentile for entering freshmen at the college level is 78.[17] Thus, the attrition group has a

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[17] Ohio College Association, Ohio State University Psychological Test, Form 21, Bulletin No. 124. Columbus, Ohio. Autumn 1940.

slightly below average O.C.A. score, and the survival group has a slightly above average O.C.A. score. The mean scientific interest scores for the attrition and survival groups were 71.40 and 77.20 respectively. The raw score corresponding to the fiftieth percentile is 68.[18] Thus, both groups indicated a slightly higher than average scientific interest. With respect to age at entrance to the University it can be noted that the average age of the attrition group was slightly higher than that of the survival group.

Finally, it can be noted from Table 1 that the first semester college mathematics mark of the survival group is slightly greater than one letter mark in excess of that of the attrition group on the average. The actual mean first-semester college mathematics mark for the attrition group was 1.37 and for the survival group was 2.57. Thus, the achievement of the attrition group was approximately 0.6 of a grade point below an average of 2.00, and the achievement of the survival group was about 0.6 of a grade point above average. Since the same system of coding was used in assigning values to mean high school mathematics mark as was used for first semester college mathematics mark, a

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[18] Science Research Associates, Profile Sheet for Men and Boys, Form BM of the Kuder Preference Record. Chicago, Illinois. 1945.

comparison of the values 0.68 and 1.20, though not completely justified, would seem to suggest that first semester college mathematics mark will be a better prediction of survival than mean high school mathematics mark.

A technique was available for arriving at an answer for the preceding proposal and for determining in general which of the eighteen prediction variables would be most useful for predicting survival. A biserial correlation was computed between each of the prediction variables and the tendency to complete successfully the pre-engineering curriculum. These biserial correlations and the corresponding tests of significance are shown in Table 2. The test of significance of a biserial correlation from zero which was used is mathematically identical with the t-test of the significance of the difference between two means with pooled variance.

The negative correlations in Table 2 were obtained for those variables for which the differences in means between the attrition and survival groups were also negative. A negative correlation is interpreted as follows: the higher the score of that particular variable the lower the tendency to survive in pre-engineering. Two of the negative correlations, those corresponding to artistic and literary interest, were significantly different from zero at the five per cent level. Nine variables yielded highly significant correlations with attrition-survival tendency.

Table 2.

Tests of Significance of Biserial Correlations Showing the Relationship Between the Prediction Variables and Attrition-Survival Tendency

Stage of Educational progress	Variable	r_{bis}	t
High school graduation	Mean high school mathematics mark	0.478	7.09[a]
	Units of high school mathematics	0.306	4.37[a]
College entrance	O.C.A.	0.386	5.52[a]
	English entrance test	0.356	5.13[a]
	Reading speed	0.212	2.99[a]
	Reading comprehension	0.323	4.63[a]
	Study habits	0.213	3.00[a]
	Age	-0.043	0.60
	Kuder Preference Record		
	Mechanical interest	-0.067	0.93
	Computational interest	0.114	1.59
	Scientific interest	0.236	3.33[a]
	Persuasive interest	-0.117	1.63
	Artistic interest	-0.143	2.00[b]
	Literary interest	0.096	1.34
	Musical interest	-0.066	0.91
	Social service interest	0.015	0.22
	Clerical interest	-0.145	2.48[b]
First semester college	First semester college mathematics mark	0.586	8.99[a]

[a] One per cent level of significance, 2.59.

[b] Five per cent level of significance, 1.96.

The two high school mathematics variables yielded correlations with attrition-survival tendency which were significantly different from zero at the one per cent level. Six variables from the college entrance examination battery yielded correlations significantly different from zero at the one per cent levels: (1) O.C.A. score, (2) English entrance test score, (3) reading speed score, (4) reading comprehension score, (5) study habits score, and (6) scientific interest score. The one variable to be used in predicting probability of survival in the third stage of educational progress, first semester college mathematics mark, yielded the highest correlation, 0.59, of any of the eighteen variables.

Thus, the preliminary analysis indicated the highly significant variables for predicting survival. The three following chapters were devoted to discriminant analysis and the resulting probability tables corresponding to the three stages of educational progress chosen for predicting survival in the pre-engineering curriculum.

VI. PROBABILITY OF SURVIVAL UPON COMPLETING HIGH SCHOOL

High school graduation was the first stage of educational progress chosen for predicting probability of survival. In the preliminary analysis both mean high school mathematics mark and number of units of high school mathematics were found to be highly significant predictors of attrition-survival tendency in the pre-engineering curriculum. It was desirable, then, to construct probability tables based on the two high school mathematics prediction variables. A two variable discriminant function was obtained according to the technique suggested by Wert, Neidt, and Ahmann.[19] This function was of the form: $a_1x_1 + a_2x_2$; where a_1 and a_2 were the coefficients derived from a system of simultaneous equations similar to those used in multiple regression analysis. This system was:

$$N\ zd_1 = a_1 \Sigma x_1^2 + a_2 \Sigma x_1x_2$$

$$N\ zd_2 = a_1 \Sigma x_1x_2 + a_2 \Sigma x_2 \quad .$$

When deviation form sums of squares were substituted in

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[19] Wert, J. E., Neidt, C. O., Ahmann, J. S., Statistical Methods in Educational and Psychological Research. Appleton, Century Crofts, Inc. 1954.

these equations the following system was obtained:

$$77.186277 = 257.50618\ a_1 + 125.9576\ a_2$$

$$65.519383 = 125.95762\ a_1 + 452.01387\ a_2\ .$$

A solution of the system of equations yielded the discriminant equation:

$$v = 0.264959\ x_1 + 0.071117\ x_2\ ,$$

where v was the $\frac{x}{\sigma}$ score in deviation form.

In order to determine the extent to which the two variable function was related to attrition-survival tendency, a multiple biserial correlation was obtained. This multiple biserial correlation was found by using the formula:

$$R_{bis} = \frac{pq}{z^2}\sqrt{\frac{\Delta}{N}}\ ,$$

where p = proportion of cases in survival group,

q = proportion of cases in attrition group,

z = height of ordinate dividing the normal curve of unit area into p and q parts, and

Δ = difference in means of predicted scores between the attrition and survival groups.

Δ was obtained from $\Delta = a_1\ Nz\ d_1 + a_2\ N_z\ d_2$; where a_1 and a_2 were the coefficients obtained by solving the aforementioned system of simultaneous equations and d_1 and d_2 were the actual differences in means of the attrition and survival

groups presented in Table 2.

Substituting values,

$$\Delta = (0.264959)(77.186277) + (0.0711168)(65.519383) ,$$

or $\Delta = 25.110728$.

Then, substituting values in the formula for biserial correlation:

$$R_{bis} = \frac{(0.23)(0.77)}{(0.303)^2} \sqrt{\frac{25.110728}{375}} = 0.498 .$$

This correlation was slightly higher than that obtained between survival tendency and mean high school mathematics mark, 0.478, and considerably higher than that between survival tendency and units of high school mathematics, 0.306.

To test the significance of the difference of the multiple biserial correlation from zero the following formula was employed:

$$F_{m,N-m-1} = \frac{\Delta(N-m-1)}{\left(\frac{Nz^2}{pq} - \Delta\right)m} ,$$

where m was the number of variables included in the correlation.

Substituting values,

$$F_{2,372} = \frac{25.110728(372)}{\left[\frac{375(0.3031)^2}{(0.23)(0.77)} - 25.110728\right] 2} = 27.50 .$$

This F value was significant far beyond the 1 per cent level. Therefore, prediction of survival upon high school graduation was linearly related to the two-variable combination of mean high school mathematics mark and units of high school mathematics.

To determine if either of the high school variables alone might be as effective in predicting survival as the combination of them, each variable in turn was dropped from the prediction equation to determine whether or not a significant loss ensued. The formula for testing the significance of the loss of a variable was:

$$F_{n,N-m-1} = \frac{(\Delta m - \Delta m - n)(N-m-1)}{\left(\frac{Nz^2}{pq} - \Delta m\right) n} ,$$

where n was the number of variables eliminated. Substituting values when eliminating units of high school mathematics from the prediction equation,

$$F_{1,372} = \frac{(25.110728 - 23.136227)372}{\left[\frac{375(0.3031)^2}{(0.23)(0.77)} - 25.110728\right] 1} = 4.33 .$$

This value of F was significant at the five per cent level. Thus, elimination of units of high school mathematics yielded a significant loss. Moreover, when mean high school mathematics mark was eliminated from the prediction equation, a highly significant loss occurred as evidenced by an F

value of 36.69. Neither variable could have been eliminated from the prediction equation without incurring a significant loss in prediction of the tendency to survive. However, the multiple biserial correlation, 0.498, corresponding to the two-variable prediction scheme, was only slightly greater than the biserial correlation, 0.478, obtained by using mean high school mathematics mark alone as a predictor of attrition-survival tendency. It seemed desirable, therefore, to construct two probability tables. To facilitate the construction of a probability table, the discriminant equation was expressed in raw score form.

The raw score formula for predicting survival from the two high school variables in sigma units was:

$$V - \bar{V} = a_1 (X_1 - \bar{X}_1) + a_2 (X_2 - \bar{X}_2) ,$$

where $\bar{V}$ was the normal deviate obtained from a normal probability table and corresponded to the percentage of students in the survival group.

Substituting values,

$$V-(-0.741155) = 0.264959(X_1-2.52165)+0.071168(X_2-2.72029) ,$$

$$\text{or } V = 0.264959\ X_1 + 0.071168\ X_2 - 1.602747 .$$

A probability table was constructed by substituting values of mean high school mathematics mark, X_1, and units

of high school mathematics, X_2, in the foregoing equation. Percentages corresponding to values of V were obtained from a normal probability table.

The chances in 100 of survival based on mean high school mathematics mark and number of units of high school mathematics were shown in Table 3. Probabilities of survival ranged from 10 chances in 100 to 40 chances in 100 as average high school mathematics mark ranged from 1.00 to 4.00 and the number of years of high school mathematics experience ranged from one to four.

The discriminant equation for predicting survival from mean high school mathematics alone was:

$$V = 0.299745\ X_1 - 1.497007\ .$$

Substituting chosen values of mean high school mathematics mark in this equation, values of V corresponding to various probabilities of survival were derived. The chances in 100 of surviving in the pre-engineering curriculum at the University of Omaha based only on mean high school mathematics mark were shown in Table 4. From this table it was seen that the chances of survival ranged from 12 in 100 to 38 in 100 as mean high school mathematics mark ranged from 1.00 to 4.00.

Approximately the same range of probability of survival was obtained when mean high school mathematics mark alone

Table 3.

Chances in 100 of Survival in Pre-Engineering Based on Mean High School Mathematics Mark and Number of Units of High School Mathematics

Mean high school mathematics mark	Number of units of high school mathematics						
	1.0	1.5	2.0	2.5	3.0	3.5	4.0
4.00	32	33	34	36	38	38	40
3.75	30	31	32	33	34	36	37
3.50	27	29	29	31	32	34	35
3.25	25	26	28	29	30	31	32
3.00	23	24	25	27	28	29	30
2.75	21	22	23	24	25	27	28
2.50	19	20	21	22	23	24	26
2.25	18	19	19	20	21	22	24
2.00	15	15	18	19	20	21	22
1.75	14	14	16	17	18	19	20
1.50	13	13	14	15	16	17	18
1.25	12	12	13	13	15	15	16
1.00	10	11	12	12	13	14	15

Table 4.

Chances in 100 of Survival in Pre-Engineering Based on Mean High School Mathematics Mark

Mean high school mathematics mark	Probability of survival
4.00	38
3.75	36
3.50	33
3.25	30
3.00	28
2.75	25
2.50	23
2.25	21
2.00	19
1.75	17
1.50	15
1.25	13
1.00	12

was used as a prediction variable as when the combination of mean high school mathematics mark and units of high school mathematics was employed. From the standpoint of ready usage the counselor will probably find the single variable probability table quite satisfactory in most instances. However, the additional information supplied by the two-variable table may in some cases be quite valuable.

VII. PROBABILITY OF SURVIVAL AFTER UNIVERSITY ENTRANCE EXAMINATIONS

The preliminary analysis yielded six variables which are found highly significant for purposes of forecasting survival from the University of Omaha entrance examination battery. These variables were: (1) O.C.A. score, (2) English entrance test score, (3) reading speed score, (4) reading comprehension score, (5) study habits test score, and (6) scientific interest score. In order to determine probabilities of survival, it was necessary to ascertain the best combination of these six variables to be used in a prediction equation. A discriminant equation based on the six variables was found in a manner similar to that of the preceding chapter.

For the college entrance examination battery the system of normal equations in deviation form was:

$$Nzd_1 = a_1\Sigma x_1^2 + a_2\Sigma x_1x_2 + a_3\Sigma x_1x_3 + a_4\Sigma x_1x_4 + a_5\Sigma x_1x_5 + a_6\Sigma x_1x_6$$

$$Nzd_2 = a_1\Sigma x_1x_2 + a_2\Sigma x_2^2 + a_3\Sigma x_2x_3 + a_4\Sigma x_2x_4 + a_5\Sigma x_2x_5 + a_6\Sigma x_2x_6$$

$$\vdots \qquad \vdots \qquad \vdots \qquad \vdots \qquad \vdots \qquad \vdots \qquad \vdots$$

$$Nzd_6 = a_1\Sigma x_1x_6 + a_2\Sigma x_2x_6 + a_3\Sigma x_3x_6 + a_4\Sigma x_4x_6 + a_5\Sigma x_5x_6 + a_6\Sigma x_6^2.$$

A solution of the system yielded the following discriminant equation:

$$v = 0.00503913x_1 + 0.000871908x_2 + 0.00806021x_3$$
$$+ 0.00226957x_4 + 0.0012009\text{4}x_5 + 0.0048510\text{4}x_6 \quad .$$

It was necessary to compute the difference in predicted means of the attrition and survival groups for substitution in the formula for multiple biserial correlation.

The difference in predicted means of the attrition and survival groups was given by the formula:

$$\Delta = a_1Nzd_1 + a_2Nzd_2 + a_3Nzd_3 + a_4Nzd_4 + a_5Nzd_5 + a_6Nzd_6 \text{ , or}$$

$$\Delta = 9.289474 + 2.729728 - 1.578721 + 2.724923 + 2.404080$$
$$+ 3.195967 = 20.344173.$$

The multiple biserial correlation based on the six variables was 0.430. This value was significantly different from zero at the 1 per cent level. The combination of six variables yielded a correlation comfortably above that obtained between attrition-survival tendency and any of the variables considered singly. The single variable most highly related to survival tendency was O.C.A. score with a correlation of 0.386.

To determine if a significant loss in forecasting efficiency might ensue, variables were systematically eliminated from the prediction scheme. From the formula for multiple biserial correlation stated in the preceding

chapter it is evident that the multiple biserial correlation coefficient is directly proportional to the square root of the difference in predicted means of the attrition and survival groups. It followed, therefore, that the variable which contributed least to the difference in predicted means also contributed least to the multiple biserial correlation.

An efficient means of determining which variable of the six-variable equation contributed least to the difference in predicted means, Δ, of the attrition and survival groups was the formula:

$$F_{1,N-m-1} = \frac{aNzd(N-m-1)}{N-\Delta_0} ,$$

where aNzd = the contribution of the absolute value of any one of the variables to the difference in predicted means, and Δ_0 = the sum of the contributions of the absolute values of all of the variables to the difference in predicted means.

The foregoing formula was evaluated by substituting from the equation for Δ the absolute value of the term corresponding to the single variable eliminated.

Relative contributions of the six variables were given by the following F values:

O.C.A. score	9.60
English entrance test score	2.82
Reading speed score	1.63
Reading comprehension score	2.82
Study habits score	2.48
Scientific interest score	3.30

A comparison of the F values indicated that reading speed score for the 375 cases contributed least to the difference in predicted means of the attrition and survival groups. It should be pointed out that the F value determining the relative contribution of any one of the variables when used in a battery is not identical with the F value for loss by the elimination of that variable except under the non-existent condition of no intercorrelation with other prediction variables.

A five-variable prediction equation was found omitting reading speed score from the prediction battery. No significant loss was incurred by dropping reading speed score from the prediction scheme. The multiple biserial correlation from the five-variable equation was 0.427.

A value for the difference in predicted means, Δ, was computed for the five-variable equation, and again an F test was applied to determine which variable contributed least to the expression for the difference in predicted means of the attrition and survival groups. The F values were:

O.C.A. score	9.71
English entrance test score	2.22
Reading comprehension score	1.61
Study habits score	2.33
Scientific interest score	3.25

Reading comprehension score was found to contribute the least to the difference in the predicted means of the two groups. Therefore, a four-variable discriminant equation was found by omitting reading comprehension score from the battery of prediction variables. No significant loss was evident in predicting from the four-variable equation rather than the five-variable equation. The F value for loss due to eliminating reading comprehension score was 0.16. The multiple biserial correlation was then 0.426.

An F test was applied to the terms of the expression for the difference in means of the attrition and survival groups corresponding to the four-variable discriminant equation. The resulting F values were:

O.C.A score	10.43
English entrance test score	3.09
Study habits test score	2.30
Scientific interest score	3.26

The study habits test score contributed least in the four-variable battery to the difference in predicted means

of the attrition and survival groups. Thus, a three-variable discriminant equation was found using O.C.A. score, English entrance test score, and scientific interest test score as the prediction variables. The loss in eliminating the study habits test score was not significant, yielding an F value of 2.03. The biserial correlation was reduced from 0.427 for the four-variable battery to 0.415 for the three-variable battery. Discriminant equations based on all combinations of two out of the three variables were developed. The usual test of significance of loss for a single variable was applied. The resulting multiple biserial correlations and corresponding tests of significance are shown in Table 5.

From Table 5 it was concluded that neither O.C.A. score nor scientific interest score could be eliminated from the

Table 5.

Combinations of O.C.A. Score, English Test Score and Scientific Interest Score in Discriminant Analysis

Variable eliminated	R_{bis}	F for loss
None	0.415	
English test score	0.411	0.68
Scientific interest score	0.390	4.21[a]
O.C.A. score	0.256	22.58[b]

[a] Significant at the five per cent level.

[b] Significant at the one per cent level.

prediction scheme without significant loss. Therefore, a discriminant equation was developed using O.C.A. score and scientific interest score as prediction variables. The discriminant equation in raw score form for these two variables was:

$$V = 0.00738715X_1 + 0.00528101X_2 - 1.652059 .$$

When various values for O.C.A. score, X_1, and scientific interest score, X_2, were substituted in the foregoing formula, the chances of survival corresponding to values of V were obtained from a normal probability table.

Chances in 100 of survival in pre-engineering at the University of Omaha based on various O.C.A. scores and scientific interest scores were shown in Table 6.

Inspection of Table 6 indicated that chances in 100 of survival in pre-engineering ranged from 6 to 46 as scientific interest score ranged from 10 to 100 and as O.C.A. score ranged from 10 to 140.

The biserial correlation between O.C.A. score alone and attrition-survival tendency, 0.386, was nearly as great as the multiple biserial correlation, 0.411, obtained by using the O.C.A. score and scientific interest score in combination. Therefore, a discriminant equation based on O.C.A. score alone was found. The equation was:

$$V = 0.00818603X - 1.324939 .$$

Table 6.

Chances in 100 of Survival in Pre-Engineering Based on O.C.A. Score and Scientific Interest Score

Scientific interest score	O.C.A. score													
	10	20	30	40	50	60	70	80	90	100	110	120	130	140
100	15	16	18	20	23	25	27	30	32	35	38	41	44	46
90	14	15	17	19	21	23	26	28	30	33	36	39	41	44
80	12	14	16	18	20	22	24	26	29	31	34	37	39	42
70	11	13	14	16	18	20	22	25	27	29	32	35	37	40
60	10	12	13	15	17	19	21	23	25	28	30	33	35	38
50	9	11	12	14	15	17	19	21	24	26	28	31	33	36
40	9	10	11	13	14	16	18	20	22	24	27	29	32	34
30	8	9	10	12	13	15	16	18	20	23	25	27	30	32
20	7	8	9	11	12	14	15	17	19	21	23	26	28	30
10	6	7	8	10	11	12	14	16	18	20	22	24	26	29

Probabilities of survival corresponding to various values of O.C.A. score were shown in Table 7.

Table 7 indicated that as O.C.A. scores ranged from 10 to 140 chances in 100 of survival in pre-engineering ranged

Table 7.

Chances in 100 of Survival in Pre-Engineering Based on O.C.A. Score

O.C.A. score	Chances in 100 of survival
140	43
130	40
120	37
110	34
100	31
90	28
80	25
70	23
60	20
50	18
40	16
30	14
20	12
10	11

from 11 to 43. For purposes of counseling the probabilities of survival based on O.C.A. score alone do not differ to any great extent from the probabilities based on both O.C.A. score and scientific interest score. However, the fact that the single variable prediction seems quite as satisfactory as the prediction of survival from two variables is not

sufficient justification for eliminating the scientific interest test from the test battery.

In the prediction of survival based on the two high school mathematics variables in the preceding section a loss significant at the one per cent level occurred only when mean high school mathematics mark was dropped from the two variable prediction equation. In the present section only the elimination of O.C.A. score from the pair of variables giving the best prediction of survival yielded a loss significant at the one per cent level. Therefore, a discriminant equation was obtained using the pair of variables which had been found to forecast survival most effectively through the time of administration of the university entrance examinations. The two variables were mean high school mathematics mark and O.C.A. score. This two variable combination provided a biserial correlation of 0.520 with survival tendency, a noticeable increase over the biserial correlations of 0.478 and 0.386 obtained by using mean high school mathematics mark and O.C.A. score alone respectively. The new two variable combination provided a biserial correlation with survival slightly greater than the 0.498 obtained by using the two high school variables and substantially greater than the 0.430 obtained from the six variables of the college entrance test battery. Elimination of either O.C.A. score or mean high school mathematics mark

Table 8.

Chances in 100 of Survival in Pre-Engineering Based on O.C.A. Score and Mean High School Mathematics Mark

Mean high school mathematics mark	O.C.A. score													
	10	20	30	40	50	60	70	80	90	100	110	120	130	140
4.00	25	26	28	30	31	33	35	37	38	40	42	44	46	48
3.75	23	25	26	28	29	31	33	34	36	38	40	42	44	45
3.50	21	23	24	26	27	29	30	32	34	36	38	39	41	43
3.25	20	21	22	24	25	27	28	30	32	33	35	37	39	41
3.00	18	19	21	22	23	25	26	28	30	31	33	35	37	38
2.75	16	18	19	20	22	23	24	26	28	29	31	33	34	36
2.50	15	16	17	19	20	21	23	24	26	27	29	30	32	34
2.25	14	15	16	17	18	20	21	22	24	25	27	28	30	32
2.00	12	13	14	15	17	18	19	21	22	23	25	26	28	30
1.75	11	12	13	14	15	16	18	19	20	22	23	24	26	28
1.50	10	11	12	13	14	15	16	17	19	20	21	23	24	26
1.25	9	10	11	12	13	14	15	16	17	18	20	21	22	24
1.00	8	9	10	10	11	12	13	14	15	17	18	19	21	22

from the prediction of survival tendency resulted in a highly significant loss. Therefore, a discriminant equation using both variables was developed. The prediction equation for the two variables in raw score form was:

$$V = 0.240739X_1 + 0.00480695X_2 - 1.69102 ,$$

where X_1 was mean high school mathematics mark, and X_2 was O.C.A. score. Substitution of values of the two variables in the equation provided the information necessary to determine the probabilities of survival shown in Table 8.

The probabilities in Table 8 indicated that chances in 100 of survival in pre-engineering ranged from 8 to 48 as mean high school mathematics mark increased from 1.00 to 4.00 and O.C.A. score increased from 10 to 140. Since mean high school mathematics mark and O.C.A. score had a considerably greater biserial correlation, 0.520, with survival tendency than the one, 0.411, obtained from the best two-variable equation developed from the college entrance test battery using O.C.A. score and scientific interest score, the probabilities presented in Table 8 seemed more satisfactory for predicting survival than the ones presented in Table 7.

VIII. PROBABILITY OF SURVIVAL AT THE END OF THE FIRST SEMESTER OF COLLEGE MATHEMATICS

By the time the students considered in the present investigation had reached the end of the first semester of mathematics at the University of Omaha, several combinations of variables were available for predicting survival in pre-engineering. The simplest prediction scheme at the end of the third stage of educational progress was a discriminant equation based on first-semester mathematics alone. A discriminant equation for predicting attrition-survival tendency based on first semester college mathematics mark alone was of the form:

$$Nzd = a\Sigma x^2 \ .$$

The value of a was found to be 0.253098, and the difference in predicted means, Δ, of the two groups of the dichotomy had a value of 34.743867. The biserial correlation between first semester college mathematics mark and survival tendency was 0.586. This biserial correlation was greater than any of the correlations obtained from the prediction schemes developed for the two preceding stages of educational progress. The discriminant equation for college mathematics mark was:

$$V = 0.254098X - 1.158553 .$$

Probabilities of survival developed from this equation were shown in Table 9. Inspection of Table 9 indicated that chances in 100 of survival in pre-engineering ranged from 13 to 44 as first semester college mathematics mark increased from failure to A.

Table 9.

Chances in 100 of Survival in Pre-Engineering Based on First Semester College Mathematics Mark

First semester college mathematics mark	Chances in 100 of survival
4	44
3	35
2	26
1	18
0	12

Attempts to predict survival were concluded with the investigation of the possibility that a combination of the three best prediction variables, one from each of the three stages of educational progress of the student, might provide the most satisfactory discriminant equation yet developed. A three-variable discriminant equation was

obtained using mean high school mathematics mark, O.C.A. score, and first semester college mathematics mark. This three-variable combination yielded a multiple biserial correlation of 0.630 as compared to 0.520 obtained from the combination of mean high school mathematics mark and O.C.A. score, the most effective combination of variables previously found. When the O.C.A. score was dropped from the three-variable prediction equation, the multiple biserial correlation was reduced only to 0.627. The loss incurred in dropping O.C.A. score was by no means significant. However, when either of the other variables was dropped from the three-variable equation, a highly significant loss occurred. Thus, the two-variable combination of first semester college mathematics mark and mean high school mathematics mark seemed to provide the most effective combination of variables for predicting survival at the end of the third stage of educational progress of the student.

One possible combination of variables valuable for predicting survival remained to be investigated. A discriminant equation was developed for predicting survival from O.C.A. score and first semester college mathematics mark. This combination yielded a multiple biserial correlation with survival tendency of 0.595. Elimination of O.C.A. score from the prediction equation did not result in a significant loss. No great loss in predictive efficiency was to be

expected, however, since the biserial correlation obtained by using first semester college mathematics mark alone to predict survival was 0.586.

Thus, the two-variable combination of first semester college mathematics mark and mean high school mathematics mark evolved as the most effective means of predicting survival in pre-engineering at the University of Omaha from the various combinations of variables investigated. The discriminant equation using the two best prediction variables was:

$$V = 0.161074X_1 + 0.200892X_2 - 1.477326 ,$$

where X_1 was mean high school mathematics mark and X2 was first semester college mathematics mark. The probability table obtained from the foregoing equation appeared in Table 10.

Inspection of Table 10 indicated that as mean high school mathematics mark ranged from 1.00 to 4.00 and first semester college mathematics mark ranged from failure to A, the probability of survival in pre-engineering increased from 13 chances in 100 to 49 chances in 100. The two-variable combination used to obtain the probabilities of survival shown in Table 10 yielded the highest correlation, 0.627, with survival found in the entire investigation. Thus, the most effective prediction of survival is available

Table 10.

Chances in 100 of Survival in Pre-Engineering Based on Mean High School Mathematics Mark and First Semester College Mathematics Mark

Mean high school mathematics mark	First semester college mathematics mark				
	0	1	2	3	4
4.00	20	26	33	41	49
3.75	19	25	32	39	47
3.50	18	24	30	38	46
3.25	17	23	29	36	44
3.00	16	21	28	35	42
2.75	15	20	26	33	41
2.50	14	19	25	32	39
2.25	13	18	24	30	38
2.00	12	17	23	29	36
1.75	11	16	21	28	35
1.50	10	15	20	26	33
1.25	9	14	19	25	32
1.00	8	13	18	24	30

to the counselor at the end of the first semester of college mathematics by using mean high school mathematics mark and first semester college mathematics mark as prediction variables.

IX. SUMMARY

The present study was devised to determine the relative importance of various factors related to student achievement, aptitude, and interest in predicting survival of students entering the pre-engineering curriculum at the University of Omaha. Probabilities of survival were computed in such a manner that the student could determine his chances in 100 of successfully completing the pre-engineering curriculum immediately after graduating from high school, after taking the university entrance examinations, or, at the latest, after completing first semester college mathematics.

The 375 students included in the investigation were graduates of Omaha, Nebraska, and Council Bluffs, Iowa, public high schools who entered the pre-engineering curriculum at the University of Omaha from September 1946, through September 1949. The criterion of survival was a passing mark in second semester calculus. Eighty-six students fell in the survival group and the remaining 289 in the attrition group.

Eighteen variables designed to measure achievement, aptitude, and interest conceivably associated with attrition-survival tendency were available from university records. Biserial correlations were computed to determine which of the

eighteen variables would be most valuable in predicting attrition-survival tendency. Eight highly significant correlations were obtained. These correlations with attrition-survival at the three stages of educational progress for which predictions were made were:

(1) Upon graduation from high school,	Mean high school mathematics mark	0.478,
	Units of high school mathematics	0.306;
(2) Upon completion of college entrance examinations,	Ohio University Psychological Examination	0.386,
	Cooperative English test	0.356,
	Minnesota test of reading speed	0.212,
	Minnesota test of reading comprehension	0.323,
	Wrenn study habits inventory	0.213,
	Kuder scientific interest	0.236;
(3) Upon completion of first semester college mathematics,	First semester college mathematics mark	0.586.

Probability tables giving chances in 100 of successfully completing the pre-engineering curriculum were prepared at each of the three stages by means of the discriminant analysis.

A discriminant function based on the two high school variables yielded a multiple biserial correlation of 0.498. As mean high school mathematics mark increased from 1.00 to 4.00 and the number of years of high school mathematics experience increased from one to four, chances of survival

ranged from 10 in 100 to 40 in 100 predicted from the two-variable combination. A significant loss in predicting efficiency resulted when either of the high school variables was eliminated from the discriminant function. However, since the biserial correlation based on mean high school mathematics mark alone was much higher than that obtained from units of high school mathematics and was nearly as great as the biserial correlation from the two-variable equation, a probability table based only on high school mathematics average was derived. Here, probabilities of survival ranged from 12 in 100 to 38 in 100 as mean high school mathematics mark increased from 1.00 to 4.00.

In order to predict probability of survival on the basis of the college entrance test battery, a six-variable discriminant function was developed. The multiple biserial correlation corresponding to the six-variable equation was 0.430. No significant loss in forecasting efficiency occurred when cooperative English test score, Minnesota reading speed and comprehension scores, and study habits inventory score were dropped from the prediction scheme. The multiple biserial correlation based on the two remaining prediction variables, Ohio State University Psychological Examination score and Kuder Scientific Interest score, was 0.411. Since the biserial correlation based on the Ohio State University Psychological Examination score was 0.386, almost as great as the multiple biserial correlation obtained

from the two-variable discriminant function, two probability tables were prepared for predicting survival from the college entrance test battery.

The probability table based on Ohio State Psychological Examination score and Kuder Scientific Interest Score indicated from 6 to 46 chances in 100 of survival as scientific interest score increased from 10 to 100 and the Ohio State Psychological Examination score increased from 10 to 140. A probability table based on Ohio State Psychological Examination score alone yielded chances of survival ranging from 11 in 100 to 43 in 100 as values of the prediction variable increased from 10 to 140.

When the analysis of the college entrance examination battery was concluded, a two-variable discriminant equation was developed using the best prediction variable discovered in each of the first two stages of educational progress. The two-variable combination of mean high school mathematics mark and O.C.A. score yielded a multiple biserial correlation of 0.520 with survival tendency. The probability table based on the two foregoing variables indicated from 8 to 48 chances in 100 of survival as mean high school mathematics mark increased from 1.00 to 4.00 and O.C.A. score increased from 10 to 140.

Probabilities of survival at the end of the third stage of educational progress were developed from two discriminant

equations. One prediction was based on first semester college mathematics mark alone. The biserial correlation between this single variable and survival tendency was 0.586, the highest found in the entire investigation based on one variable only. Chances of survival predicted from first semester college mathematics mark ranged from 12 in 100 to 44 in 100 as the mathematics mark increased from failure to A. When mean high school mathematics mark was used in combination with first semester college mathematics mark, the multiple biserial correlation was 0.630. This was the highest correlation found between survival tendency and the various combinations of variables investigated. Chances of survival ranged from 13 in 100 to 49 in 100 as mean high school mathematics mark increased from 1.00 to 4.00 and first semester college mathematics mark increased from failure to A.

According to the evidence presented in the present investigation, the most effective prediction of survival in pre-engineering is available after the student has completed the first semester of college mathematics. Although the prediction of successful completion of the pre-engineering curriculum at the University of Omaha cannot be carried out with more than a reasonable degree of accuracy, it is still possible to give advice, within limitations, to a student concerning his probability of success based on certain evidences of his ability and past achievement.

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